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(54) **APPARATUSES INCLUDING A PLATE HAVING A RECESS AND A CORRESPONDING PROTRUSION TO DEFINE A CHAMBER**

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(51) **Int. Cl.**

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***B41J 2/14*** (2006.01)
***B41J 2/16*** (2006.01)

(52) **U.S. Cl.**

CPC .............. ***B41J 2/1433*** (2013.01); ***B41J 2/1404*** (2013.01); ***B41J 2/162*** (2013.01); ***B41J 2/1625*** (2013.01); ***B41J 2/1628*** (2013.01); ***B41J 2/1631*** (2013.01); ***B41J 2/1642*** (2013.01); *B41J 2/1639* (2013.01); *B41J 2202/11* (2013.01); *Y10T 29/49432* (2015.01)

(58) **Field of Classification Search**

CPC .......... B41J 2/135; B41J 2/14; B41J 2/14016; B41J 2/1404; B41J 2/1433; B41J 2002/14411; B41J 2/14153; B41J 2002/14354; B41J 2/16579; B41J 2002/14403; B41J 2/1603

See application file for complete search history.

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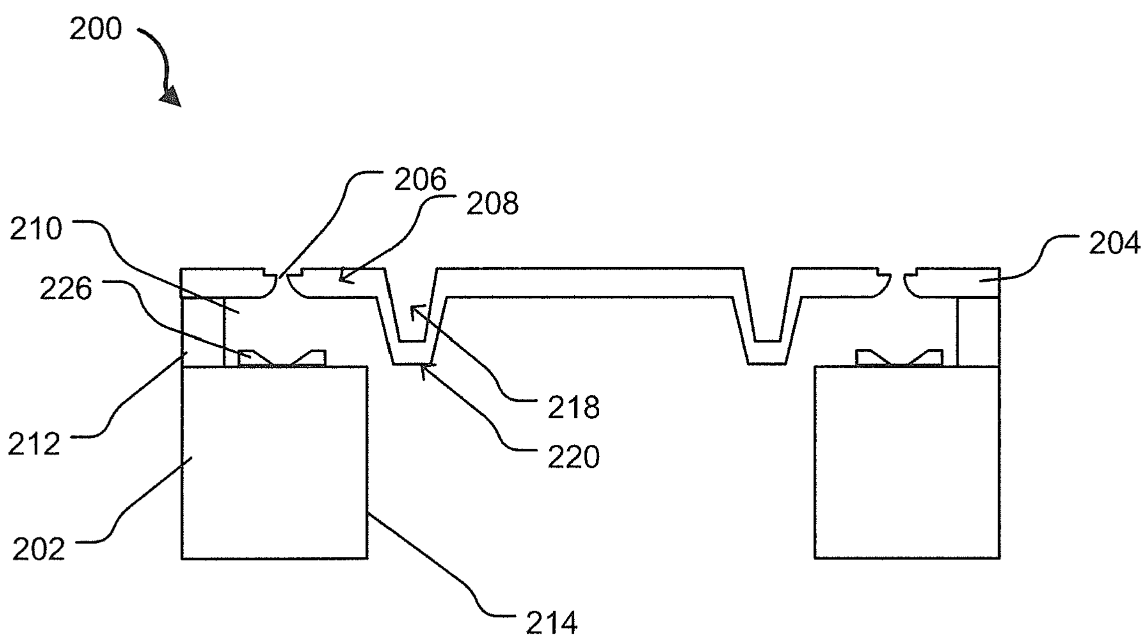
(57) **ABSTRACT**

An example provides an apparatus including a plate having a nozzle orifice, a flat portion, and a first surface having a recess forming a corresponding protrusion extending from a second surface, opposite first surface, of the plate. A substrate may be in spaced relation to the flat portion of the plate such that the protrusion extends toward the substrate and such that the flat portion and the substrate define, at least in part, a chamber.

**13 Claims, 14 Drawing Sheets**



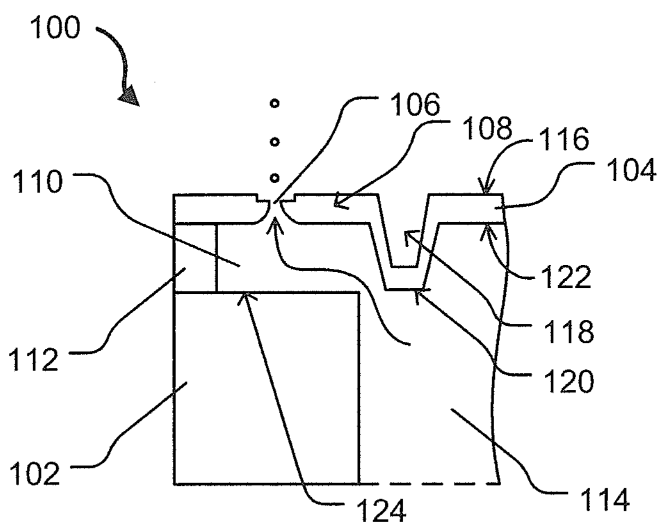



Figure 1

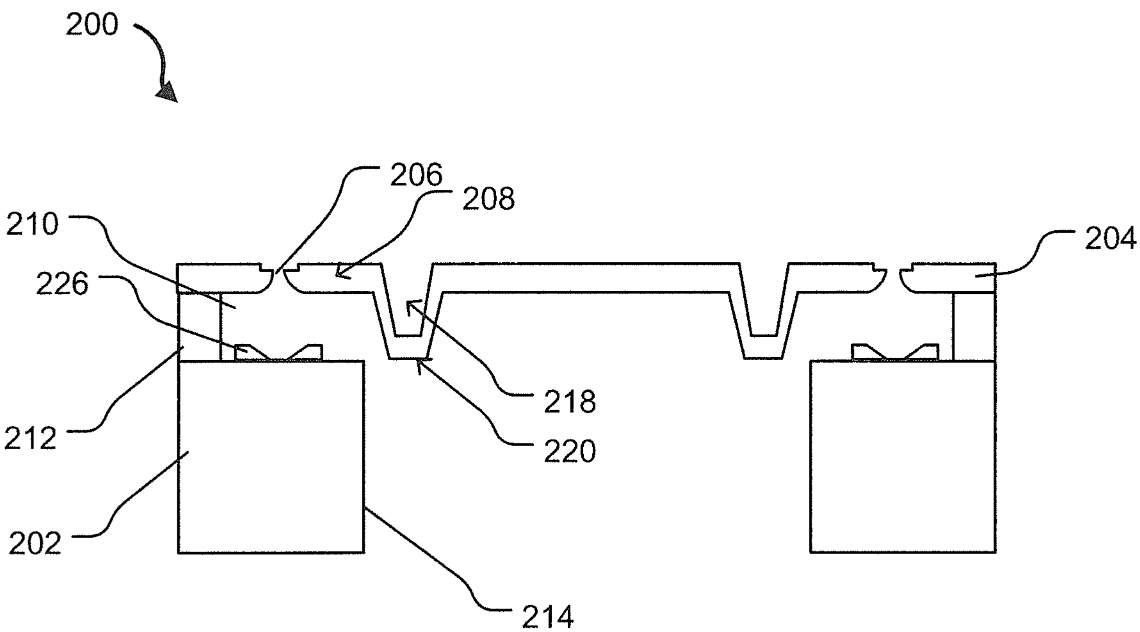



Figure 2

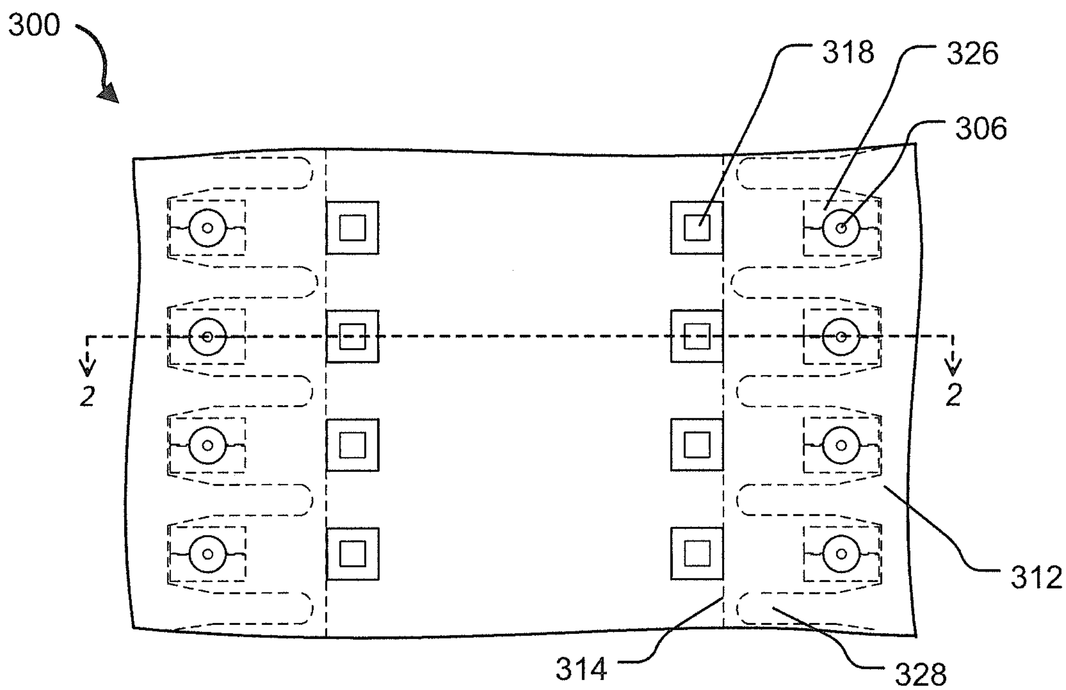



Figure 3

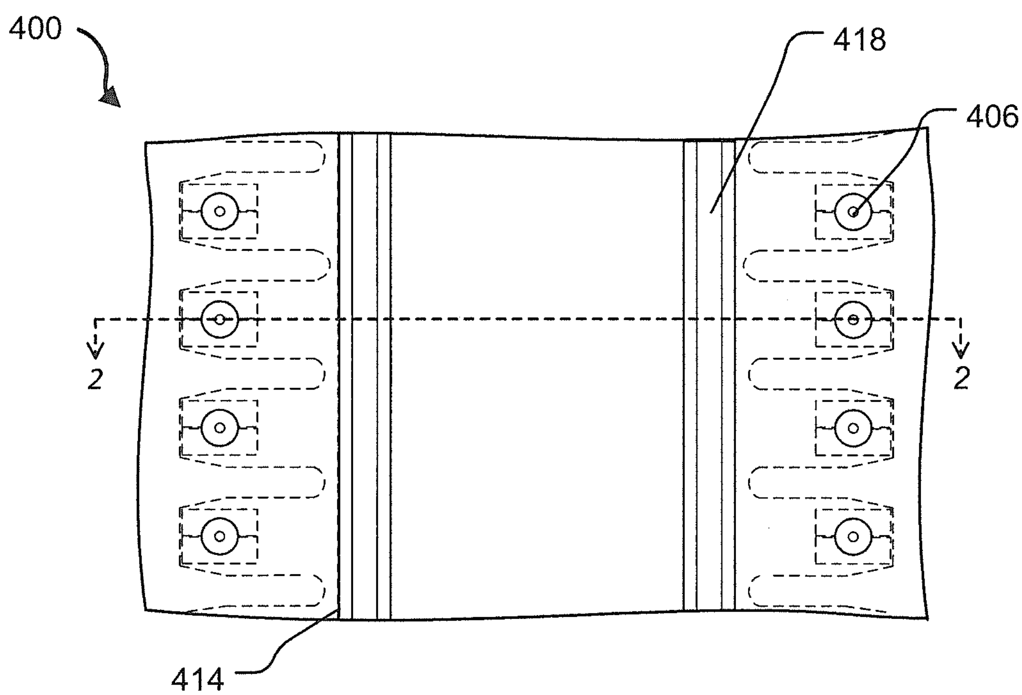



Figure 4

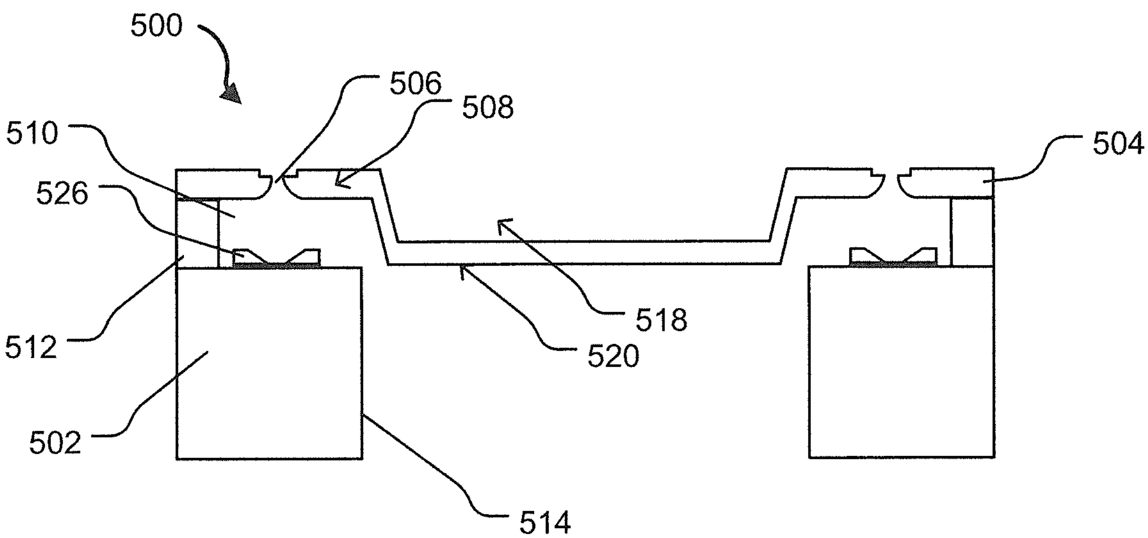



Figure 5

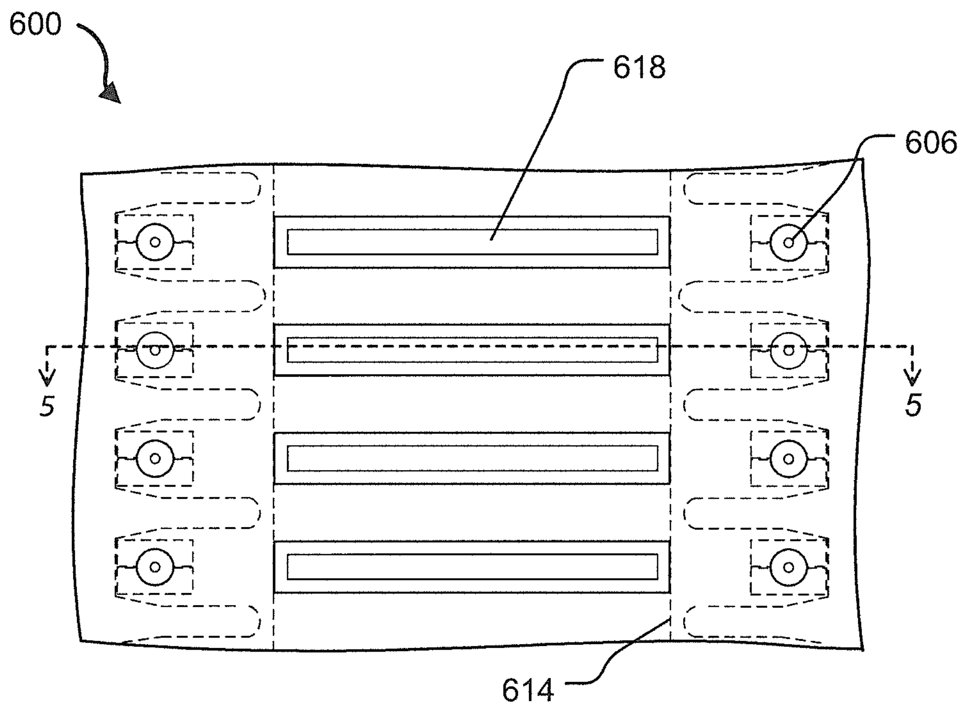



Figure 6

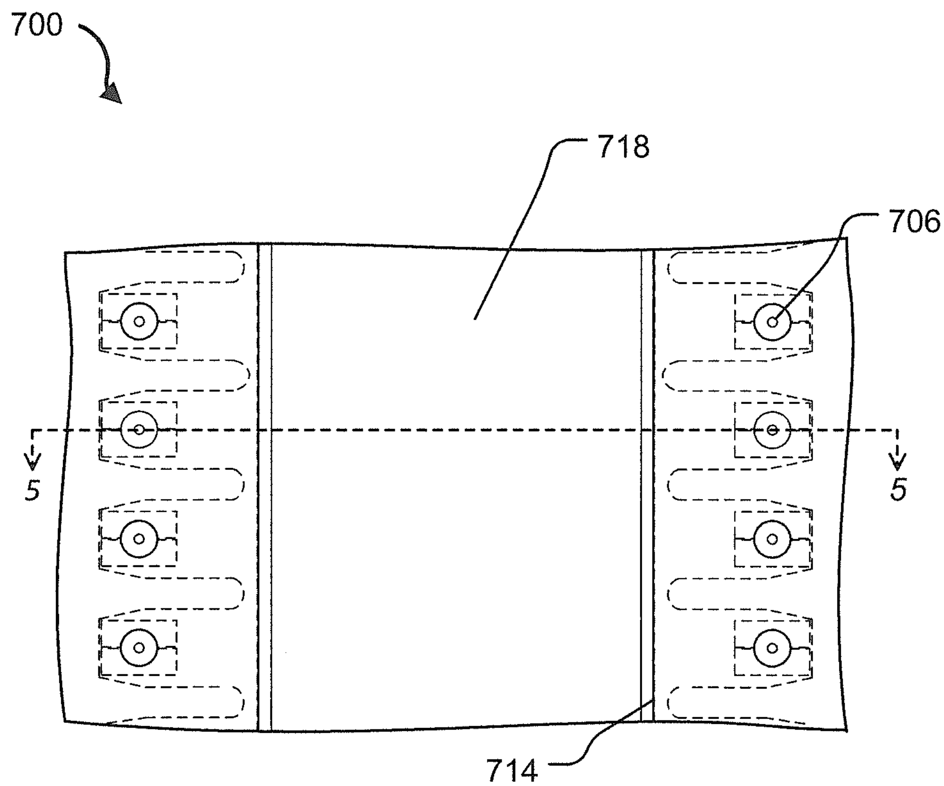



Figure 7

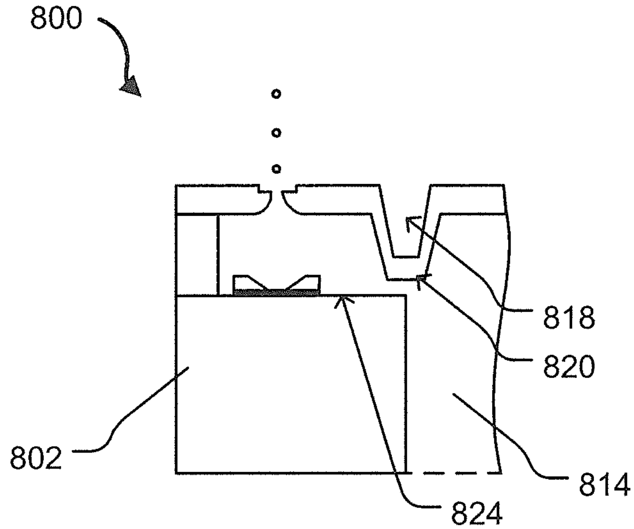



Figure 8

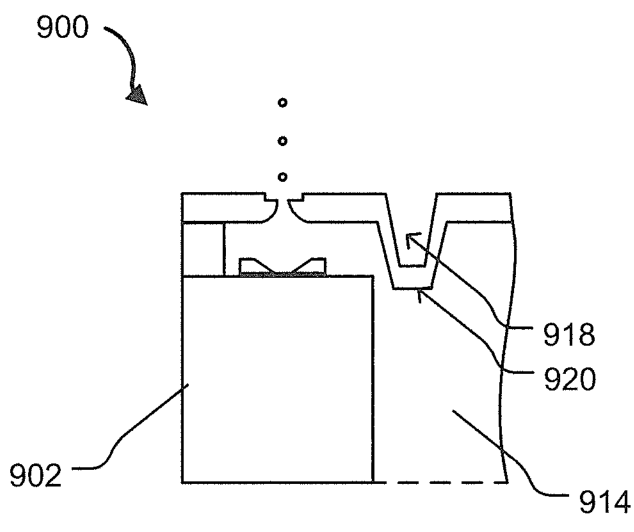



Figure 9

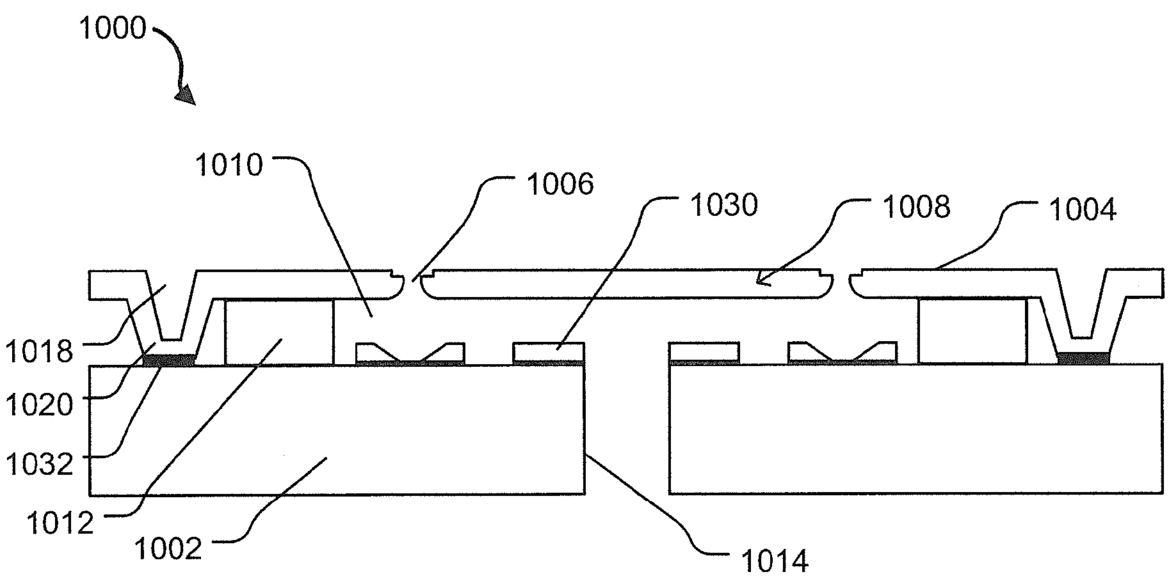



Figure 10

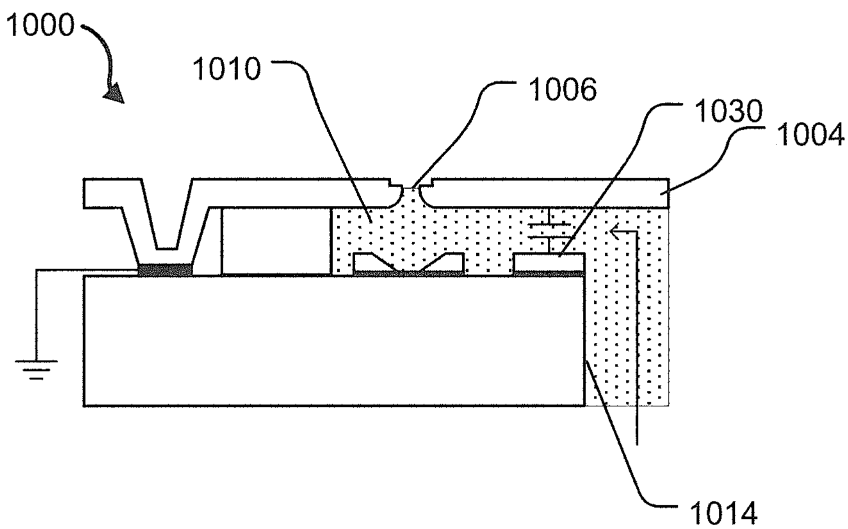



Figure 11

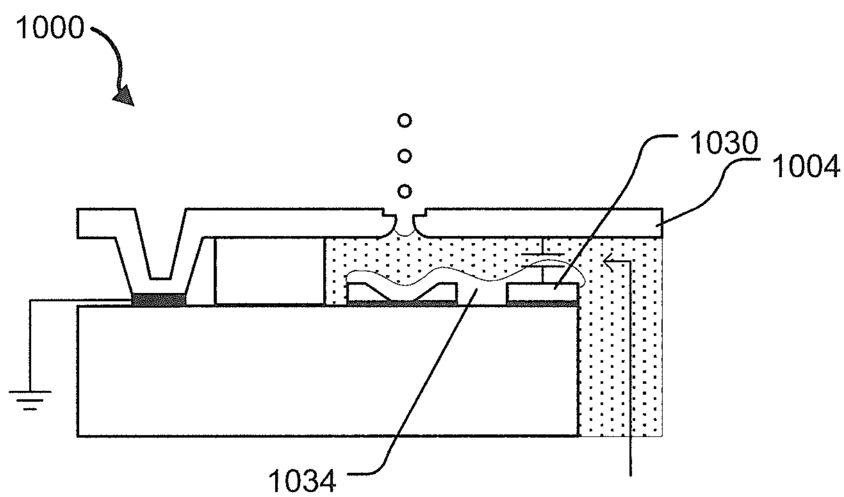



Figure 12

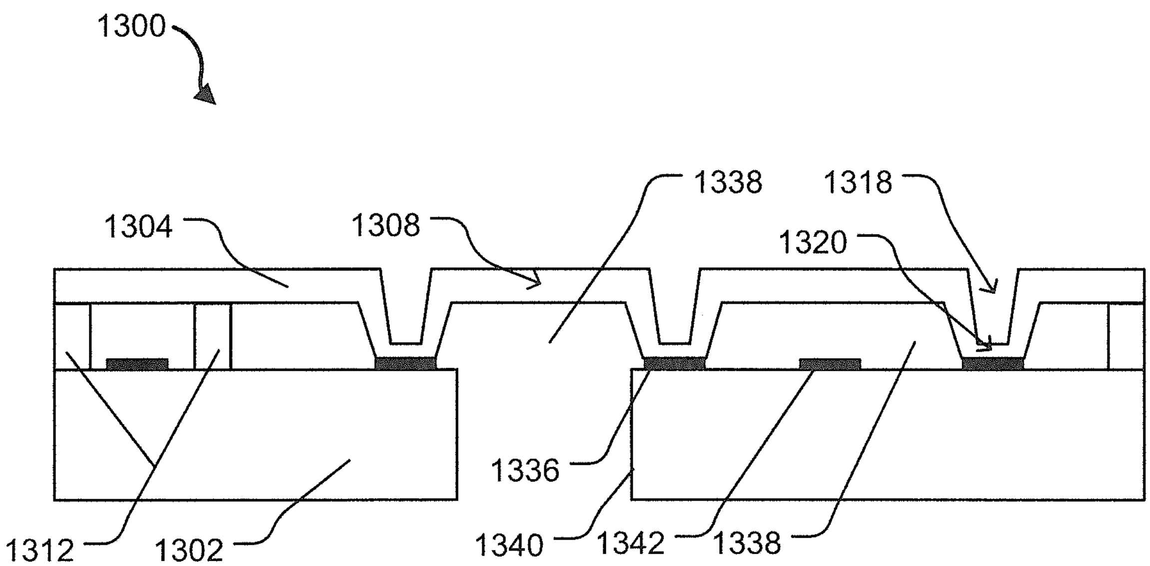



**Figure 13**


Figure 14

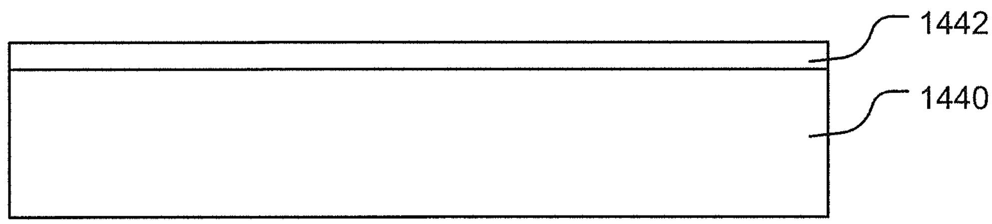



Figure 15

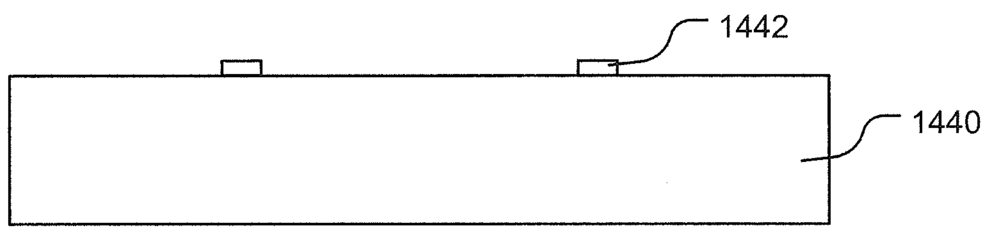



Figure 16

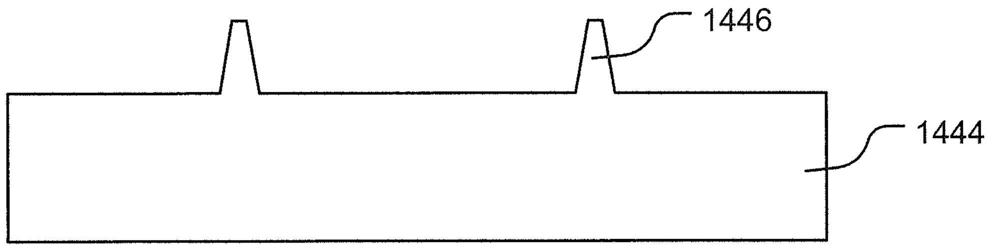



Figure 17

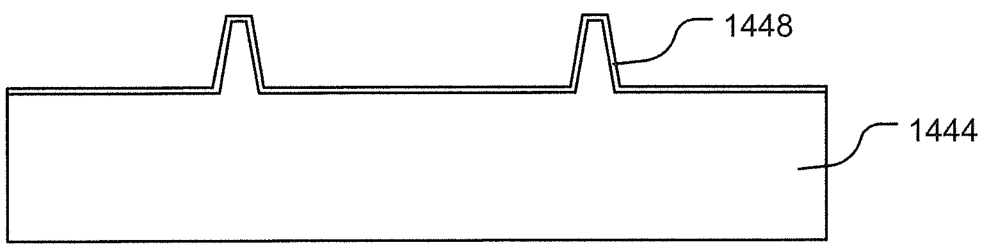



Figure 18

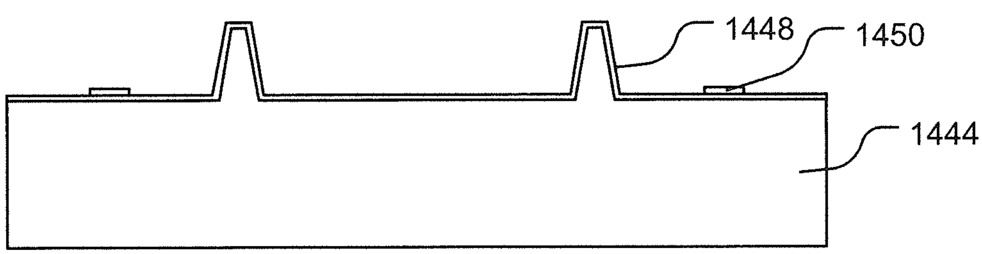



Figure 19

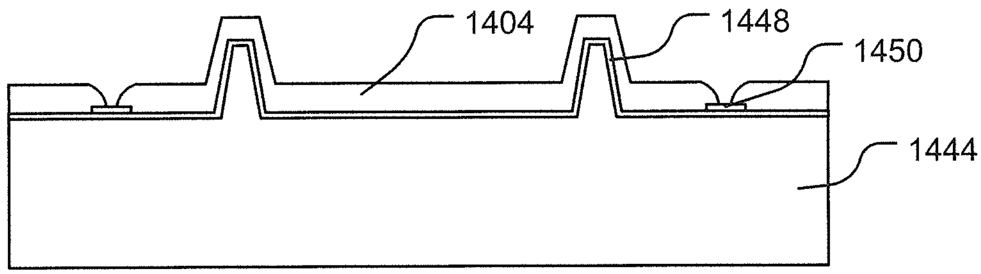



Figure 20

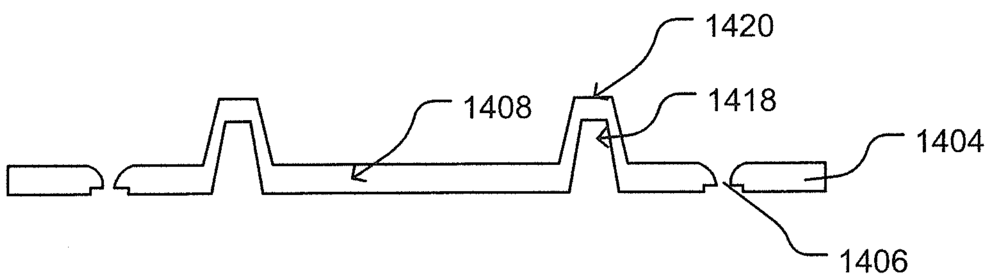



Figure 21

# APPARATUSES INCLUDING A PLATE HAVING A RECESS AND A CORRESPONDING PROTRUSION TO DEFINE A CHAMBER

## BACKGROUND

A number of devices may be implemented with voids (such as, e.g., a chamber or channel) within layers of the device. Printheads, for example, may include firing chambers, ink feed slots, or ink channels. Micro-electrical-mechanical systems devices may include air chambers to house components and/or to provide functionality to the devices. In some of these examples, layers may be separated by forming multiple layers and etching voids in the layers and then bonding another layer onto the built-up layers.

## BRIEF DESCRIPTION OF THE DRAWINGS

The Detailed Description section references the drawings, wherein:

FIGS. **1-12** illustrate various examples of example fluid ejection apparatuses;

FIG. **13** illustrates an example MEMS-based apparatus; and

FIGS. **14-21** illustrate various stages of methods for forming an apparatus including a plate having a recess and a corresponding protrusion to define a chamber;

all in which various embodiments may be implemented.

Certain examples are shown in the above-identified figures and described in detail below. The figures are not necessarily to scale, and various features and views of the figures may be shown exaggerated in scale or in schematic for clarity and/or conciseness.

## DETAILED DESCRIPTION

Device features continue to decrease in size. Printheads, for instance, may realize improved print quality as the number of nozzles increase. Devices that incorporate micro-and-smaller electrical-mechanical systems (generally referred to herein as "MEMS") devices, by definition, as very small and continue to serve a broad range of applications in a broad range of industries.

Fabrication of small device features cost-effectively and with high performance and reliability, however, continues to challenge process designers. Continuing with the printhead example, an increased number of nozzles and/or decreased printhead size may sometimes take the form of shorter shelf lengths or decreased spacing between barrier peninsulas, or both, which may limit the available spacing for barrier islands for filtering out particles in a printing fluid before reaching the nozzles.

Described herein are implementations of apparatuses including a plate having a recess and a corresponding protrusion to define a chamber between the plate and a substrate. In various implementations, the protrusion may filter particles from a fluid from entering a firing chamber of a fluid ejection apparatus. In further implementations, the protrusion of the plate may be in electrical contact with an on-substrate bond pad while the flat portion of the plate may capacitively couple with a capacitor terminal on the substrate to detect air bubbles in the fluid. In still further implementations, the plate may be incorporated into any number of MEMS-based apparatuses.

An example fluid ejection apparatus **100** is illustrated in FIG. **1**. As illustrated, the apparatus **100** may include a substrate **102** and a plate **104** having at least one nozzle orifice



**106** through which drops of a fluid (such as, e.g., ink, etc.) may be ejected. The substrate **102** may be in spaced relation to a flat portion **108** of the plate **104** such that the flat portion **108** and the substrate **102** define, at least in part, a firing chamber **110**. In some implementations, the apparatus **100** may include a barrier layer **112** between the substrate **102** and the plate **104**. The barrier layer **112** may help define the firing chamber **110**, as described elsewhere. In various implementations, the apparatus **100** may comprise, at least in part, a printhead or printhead assembly. In some implementations, for example, the fluid ejection apparatus **100** may be an inkjet printhead or inkjet printing assembly.

The substrate **102** may include a fluid feed slot **114** to provide a supply of fluid to the nozzle orifice **106** via the firing chamber **110**. In many implementations, the apparatus **100** may include a plurality of firing chambers **110** fluidically coupled to at least one of a plurality of nozzle orifices similar to the nozzle orifice **106** illustrated, and in at least some of these implementations, the fluid feed slot **114** may provide fluid to all or most of the plurality of nozzle orifices via corresponding ones of the firing chambers **110**.

A first surface **116** of the plate may include a recess **118** forming a corresponding protrusion **120** integral to the plate **104** and extending from a second surface **122** toward the fluid feed slot **114** of the substrate **102**, as illustrated. In various implementations, the protrusion **120** may filter particles in the fluid from entering the firing chamber **110** as the fluid flows from the fluid feed slot **114** to the firing chamber **110**, and this filtering may help avoid clogging of the nozzle orifice **106** as compared to a structure without the protrusion **120**.

The plate **104** may comprise one layer or multiple layers of metal or another conductive material resistant to corrosion and/or mechanical damage. In various implementations, the plate **104** may comprise nickel, gold, platinum, palladium, rhodium, titanium, or another metal or alloys thereof. In some implementations, the plate **104** may comprise an electroplated layer of at least one of gold, palladium, rhodium, or another metal. As described more fully elsewhere, the plate **104** may be separately formed from one or more other components of the apparatus **100** and then coupled to the substrate **102**. As such, rather than forming barrier structures on the substrate **102**, typically on the shelf **124**, which may have limited spacing, using the plate **104** real estate may allow for particle protection without the use of complex fabrication techniques. In various implementations, the plate **104** may allow for continued decrease in device size.

FIGS. **2-9** illustrate various examples of configurations for a plate that may be used for various implementations described herein. FIG. **2** illustrates a sectional view of an example apparatus **200** including a substrate **202** coupled to a plate **204** by a barrier layer **212**. The plate **204** includes at least one nozzle orifice **206**. The flat portion **208** of the plate **204**, the substrate **202**, and the barrier layer **212** define, at least in part, a plurality of firing chambers **210**. The plate **204** includes recesses **218** forming corresponding protrusions **220** integral to the plate **204** and extending toward the substrate **202** to filter particles in a fluid from entering the firing chamber **210** as the fluid flows from a fluid feed slot **214** to the firing chamber **210**.

The apparatus **200** further includes an actuator **226** in each firing chamber **210**. The actuators **226** may be configured to deflect into a corresponding one of the firing chambers **210** to cause fluid to be ejected through a corresponding one of the nozzle orifices **206**. In some implementations, the actuators **226** may comprise resistive or heating elements. In some implementations, the actuators **226** comprise split resistors or single rectangular resistors. Other types of actuators such as, for example, piezoelectric actuators or other actuators may be used for the actuators **226** in other implementations.

FIG. **3** and FIG. **4** illustrate examples of fluid ejection apparatuses **300** and **400**, respectively, that may have sectional views similar to that shown in FIG. **2**, with underlying layers shown with hashed lines. In FIG. **3**, the apparatus **300** includes a plate having multiple recesses **318** forming corresponding protrusions (not explicitly shown here), with a recess **318**/protrusion per each nozzle orifice **306**. The apparatus **300** further includes actuators **326**. The substrate **302** may be coupled to the plate **304** by a barrier layer **312**. As illustrated, the barrier **312** includes peninsulas **328** extending toward the fluid feed slot **314** to define the individual firing chambers.

In FIG. **4**, the apparatus **400** includes a plate having a recess **418** with corresponding protrusion (not explicitly shown here) along each column of nozzle orifices **406**, rather than individual recesses **418**/protrusions for each nozzle orifice **406**.

FIG. **5** illustrates a sectional view of an example apparatus **500** including a substrate **502** coupled to a plate **504** by a barrier layer **512**. The plate **504** includes at least one nozzle orifice **506** and a corresponding actuator **526**. The flat portion **508** of the plate **504**, the substrate **502**, and the barrier layer **512** define, at least in part, a plurality of firing chambers **510**. The plate **504** includes a recess **518** forming a corresponding protrusion **520** integral to the plate **504** and extending toward the substrate **502** to filter particles in a fluid from entering the firing chambers **510** as the fluid flows from a fluid feed slot **514** to the firing chamber **510**. As illustrated, the recess **518**/protrusion **520** spans across the apparatus **100** to filter particles for nozzle orifices **506** on both sides of the apparatus **500**.

FIG. **6** and FIG. **7** illustrate examples of fluid ejection apparatuses **600** and **700**, respectively, that may have sectional views similar to that shown in FIG. **5**, with underlying layers shown with hashed lines. In FIG. **6**, the apparatus **600** includes a plate having multiple recesses **618** forming corresponding protrusions (not explicitly shown here) spanning across the fluid feed slot **614**, with a recess **618**/protrusion per pair of nozzle orifices **606**. In FIG. **7**, the apparatus **700** includes a plate having a recess **718** forming a corresponding protrusion (not explicitly shown here) spanning across the fluid feed slot **714**, with the recess **718**/protrusion forming a particle filter for the plurality of the nozzle orifices **706**, as illustrated.

Although the various implementations of the plate illustrated thus far depict the recess/protrusion of the plate as being directly over the fluid feed slot and separated from the substrate by a distance no greater than a height of the protrusion, other configurations may be possible. FIG. **8**, for example, illustrates a fluid ejection apparatus **800** including the recess **818**/protrusion **820** partially over the fluid feed slot **814** and partially over the shelf **824** of the substrate **802**. FIG. **9** illustrates a fluid ejection apparatus **900** including the recess **918**/protrusion **920** over the fluid feed slot **914** but also sitting closer to the substrate **902** such that the protrusion **920** dips into the fluid feed slot **914**, as illustrated. Numerous other configurations may be possible within the scope of the present disclosure.

The plate of the present disclosure may be used for a wide variety of fluid-ejection and non-fluid-ejection applications. FIG. **10** illustrates another fluid ejection apparatus **1000** that may include a plate **1004** to form part of an air bubble detector to detect air bubbles in a fluid in the fluid chamber **1010**. Detection of an air bubble and/or length of time an air bubble is detected in the firing chamber **1010** may provide information regarding the performance of the apparatus **1000**. For instance, detecting an air bubble may simply provide an indication as to whether the nozzle orifice **1006**/firing chamber **1010** ejected fluid. In some implementations, if an air bubble is detected for a long-then-expected period, this may indicate a low ink level, fluid feed slot **1014** noise, some other performance-related issue, or a combination thereof.

As illustrated in FIG. **10**, the apparatus **1000** includes a substrate **1002** coupled to a flat portion **1008** of the plate **1004** by a barrier layer **1012**. The plate **1004** includes a plurality of nozzle orifices **1006** with corresponding actuators **1026**. The flat portion **1008** of the plate **1004**, the substrate **1002**, and the barrier layer **1012** define, at least in part, a plurality of firing chambers **1010** to fluidically couple the nozzle orifice **1006** with the fluid feed channel **1014**. As in other implementations, the plate **1004** includes recesses **1018** forming corresponding protrusions **1020** integral to the plate **1004** and extending toward the substrate **1002**

The apparatus **1000** may include a circuit pattern having a first capacitor terminal **1030** within the firing chamber **1010** and a bond pad **1032** external to the firing chamber **1010**, as illustrated. In this implementation, the protrusions **1020** may be in electrical contact with the substrate **1002** by the on-substrate bond pad **1032**. The flat portion **1008** of the plate **1004** may form a second capacitor terminal to capacitively couple with the first capacitor terminal **1030** to determine the presence of an air bubble in a fluid in the firing chamber **1010**, as illustrated in FIG. **11** and FIG. **12**.

As shown in FIG. **11**, as fluid flows through the fluid feed slot **1014** to the firing chamber **1010** and then to the nozzle orifice **1006**, without an air bubble, the capacitance as measured between the first capacitor terminal **1030** and the plate **1004** (the second capacitor terminal) may be a first capacitance value. On firing of the fluid from the nozzle orifice **1006**, as illustrated in FIG. **12**, an air bubble **1034** may appear in the fluid between the first capacitor terminal **1030** and the plate **1004**, which may provide a second capacitance value. Detection of a change in the capacitance values measured between the first capacitor terminal **1030** and the plate **1004** may indicate the presence of an air bubble **1034**.

The plates described herein may also be included in MEMS applications such as, but not limited to, microphones, pressure sensors (e.g., variable capacitance pressure sensors, etc.), radio-frequency devices, etc. By coupling a substrate with a protrusion of the plates described herein, complicated and costly build-up and/or multiple-wafer bonding processes may be avoided or minimized.

FIG. **13** illustrates an example MEMS-based apparatus **1300** including a plate **1304** having recesses **1318** with corresponding protrusions **1320**. A substrate **1302** may be coupled to a flat portion **1308** of the plate **1304** by a barrier layer **1312**. The protrusions **1320** may be in electrical contact with bond pads **1336** of a circuit pattern of the substrate **1302**. As illustrated, the protrusions **1320** extend toward the substrate **1302** such that the flat portion **1308** of the plate **1304** is in spaced relation to the substrate **1302** to define at least one chamber **1338**.

In various implementations, the substrate **1302** may include a trench **1340**. In some of these latter implementations, the apparatus **1300** may be a pressure sensor and the trench **1340** may comprise a pressure inlet of the sensor. In other implementations, the circuit pattern of the substrate **1302** may include a capacitor terminal **1342** to capacitively couple with the flat portion **1308** of the plate to form a variable capacitance pressure sensor. Numerous other MEMS applications may be possible within the scope of the present disclosure.

Various operations of methods for forming an apparatus including a plate, or a system including such an apparatus, is illustrated in FIGS. **14-22** by way of sectional views of the apparatus at various stages of the methods. It should be noted that various operations discussed and/or illustrated may be generally referred to as multiple discrete operations in turn to help in understanding various implementations. The order of description should not be construed to imply that these operations are order dependent, unless explicitly stated. Moreover, some implementations may include more or fewer operations than may be described.

Turning now to FIG. **14**, a method for forming an apparatus with a plate, in accordance with various implementations, may begin or proceed with providing a mandrel **1440**. The mandrel **1440** may comprise glass, soda-lime-silica glass, or another material onto which a metal may be sputtered or otherwise formed in accordance with one or more operations described herein.

At FIG. **15**, a masking material **1442** may be formed over the mandrel **1440**, as illustrated. The masking material **1442** may typically comprise a photoresist material, either positive or negative, that may be patterned through exposure and development. In other implementations, a hard mask may be used.

At FIG. **16**, the masking material **1442** may be patterned to form a pattern. The pattern may comprise a pattern defining locations of the recesses/protrusions of the plate described herein to be later-formed.

At FIG. **17**, the masked mandrel **1440** may be etched to form a patterned mandrel **1444**. In various implementations, the masked mandrel **1440** may be etched by a wet operation using hydrogen fluoride or another suitable etchant or by a dry etch through a plasma etchant. The patterned masking material **1442** may be removed either during the etching operation or subsequent thereto. In some implementations, the patterned mandrel **144** may be etched again after the patterned masking material **1442** is removed. The resultant patterned mandrel **1444** may comprise elongated, trapezoidal, conical, or otherwise shaped structure(s) **1446**.

At FIG. **18**, a layer **1448** of metal may be formed over the patterned mandrel **1444** to form the mask with which the plate may be formed. In various implementations, the layer **1448** may be formed using any suitable physical deposition operation such as, but not limited to, sputter deposition. In various implementations, the layer **1448** may comprise stainless steel and/or chrome or another material onto which the plate may be electroplated, as described herein.

For implementations of the plate including nozzle orifices, the mask may include features **1450** to define the locations of the nozzle orifices, as illustrated in FIG. **19**. In various implementations, the features **1450** may be formed by one or more patterning operations such as, but not limited to, plasma-enhanced chemical vapor deposition (PECVD) of the mask material and then patterning of the mask material. In various implementations, the mask material, and resultant features **1450**, may comprise silicon carbide or another suitable non-conductive material.

For implementations without nozzle orifices, such as, for example, various MEMS-based apparatuses, the operation(s) of FIG. **19** may be omitted altogether.

At FIG. **20**, the mask comprising the patterned mandrel **1444**, the metal layer **1448**, and the nozzle pattern features **1450** (when present) may be electroplated with a conductive material to form the plate **1404**. In various implementations, the plate **1404** may be formed by immersing the mask into a plating bath that plates the mask everywhere except where the non-conductive nozzle orifice features **1450** are located. The metal from the plating bath, thus, may define the pattern(s), shape(s) and/or feature(s) of the plate **1404**. In various implementations, the plating bath may comprise nickel, gold, platinum, rhodium, titanium, or another suitable material for the plate **1404**.

At FIG. **21**, the mask having the plate **1404** electroplated thereon may be removed from the electroplating bath, and the plate **1404** may be removed from the mask. As illustrated, the plate **1404** includes nozzle orifices **1406** and recesses **1418** with corresponding protrusions **1420**. As noted herein, in some implementations, the nozzle orifices **1406** may be omitted altogether. The plate **1404** may then be coupled to a substrate such that the protrusion **1420** extends towards the substrate and such that the flat portion **1408** of the plate **1404** is in spaced to the substrate to define a chamber (such as, e.g., a firing chamber of a fluid ejection apparatus, an air chamber of a MEMS-based device, etc.).

Various aspects of the illustrative embodiments are described herein using terms commonly employed by those skilled in the art to convey the substance of their work to others skilled in the art. It will be apparent to those skilled in the art that alternate embodiments may be practiced with only some of the described aspects. For purposes of explanation, specific numbers, materials, and configurations are set forth in order to provide a thorough understanding of the illustrative embodiments. It will be apparent to one skilled in the art that alternate embodiments may be practiced without the specific details. In other instances, well-known features are omitted or simplified in order not to obscure the illustrative embodiments.

The phrases “in an example,” “in various examples,” “in some examples,” “in various embodiments,” and “in some embodiments” are used repeatedly. The phrases generally do not refer to the same embodiments; however, they may. The terms “comprising,” “having,” and “including” are synonymous, unless the context dictates otherwise. The phrase “A and/or B” means (A), (B), or (A and B). The phrase “A/B” means (A), (B), or (A and B), similar to the phrase “A and/or B”. The phrase “at least one of A, B, and C” means (A), (B), (C), (A and B), (A and C), (B and C), or (A, B and C). The phrase “(A) B” means (B) or (A and B), that is, A is optional. Usage of terms like “top”, “bottom”, and “side” are to assist in understanding, and they are not to be construed to be limiting on the disclosure.

Although certain embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a wide variety of alternate and/or equivalent embodiments or implementations calculated to achieve the same purposes may be substituted for the embodiments shown and described without departing from the scope of this disclosure. Those with skill in the art will readily appreciate that embodiments may be implemented in a wide variety of ways. This application is intended to cover any adaptations or variations of the embodiments discussed herein. It is manifestly intended, therefore, that embodiments be limited only by the claims and the equivalents thereof.

What is claimed is:

**1**. A fluid ejection apparatus comprising:

a plate including a nozzle orifice, a flat portion, and a first surface having a recess forming a corresponding protrusion extending from a second surface, opposite the first surface, of the plate; and

a substrate in spaced relation to the flat portion of the plate such that the protrusion extends toward and is separated from the substrate and such that the flat portion and the substrate define, at least in part, a firing chamber.

**2**. The apparatus of claim **1**, wherein an end of the protrusion extends toward and is exposed to a fluid feed slot of the substrate, the fluid feed slot to provide a fluid to the firing chamber, the substrate and the protrusion defining a filter therebetween to filter particles in the fluid from entering the firing chamber.

**3**. The apparatus of claim **2**, wherein the end of the protrusion extends at least partially over the fluid feed slot.

**4**. The apparatus of claim **2**, wherein the end of the protrusion extends at least partially over the substrate.

**5**. The apparatus of claim **2**, wherein the end of the protrusion extends partially over the fluid feed slot and partially over the substrate.

**6**. The apparatus of claim **2**, wherein the end of the protrusion extends below a surface of the substrate and into the fluid feed slot.

**7**. The apparatus of claim **1**, wherein the plate includes a plurality of other protrusions extending from the first surface of the plate and wherein the flat portion and the substrate define a plurality of other firing chambers, the substrate and each of the plurality of other protrusions defining a filter therebetween to filter particles from entering corresponding ones of the plurality of other firing chambers.

**8**. The apparatus of claim **1**, wherein the flat portion and the substrate define a plurality of other firing chambers, the substrate and the protrusion defining a filter therebetween to filter particles from entering corresponding ones of the plurality of other firing chambers.

**9**. The apparatus of claim **1**, further comprising a barrier layer coupling the flat portion of the plate to the substrate and further defining the firing chamber.

**10**. The apparatus of claim **1**, wherein the plate comprises nickel, gold, platinum, palladium, rhodium, or titanium.

**11**. The apparatus of claim **1**, wherein the apparatus is a printhead or a printing apparatus.

**12**. The apparatus of claim **1**, wherein the protrusion is separated from the substrate by a distance no greater than a height of the protrusion.

**13**. A fluid ejection apparatus comprising:

a plate including a nozzle orifice, a flat portion, and a first surface having a recess forming a corresponding protrusion extending from a second surface, opposite the first surface, of the plate; and

a substrate in spaced relation to the flat portion of the plate such that the protrusion extends toward the substrate and such that the flat portion and the substrate define, at least in part, a firing chamber,

wherein the substrate includes a circuit pattern including a first capacitor terminal within the firing chamber and a bond pad on the substrate and external to the firing chamber, and wherein the protrusion is in electrical contact with the bond pad and the flat portion forms a second capacitor terminal to capacitively couple with the first capacitor terminal to determine a presence of a bubble in a fluid in the firing chamber.

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